EFFECTS OF POLLUTANTS ON DIFFERENT ORGANS OF CERTAIN TELEOSTS

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SALIM SULTAN

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DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
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Sardar Mahmood Khan,
M.Sc., Ph.D.

CERTIFICATE

I certify that " Effects of pollutants on different organs of certain teleosts" is the original work of Salim Sultan and is suitable for submission for the award of the degree of Master of Philosphy of the Aligarh Muslim University, Aligarh. This work has been done by the candidate under my supervision.

Sardar Mahmood Khan
Lecturer,
Department of Zoology,
Aligarh Muslim University,
Aligarh - 202001

28/3/81

[redacted]

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Salim Sultan

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INTRODUCTION

It is known that pollution apart from being hazardous to public health, causes serious damage to one of our important natural resources, the fisheries. Due to constant increase in population and the fast expanding pace of industrialisation in India many of our fresh water environments are made to carry an increasing load of sewage and industrial wastes. Though a good deal of information is available on the toxicity of different pollutants (pesticides, heavy metals and other chemicals) in general as such not much is known regarding histopathological effects induced by heavy metals including copper, mercury and cadmium etc.

The determination of histopathological effects of pollutants on the different organs of fishes is an important basic effort leading to our understanding of true impact of pollutants on that ecosystem because the fresh water fishes show dissimilar pattern of responses when exposed to various metals. The extent of damage vary both with body part, nature of metal, medium and duration of tests. Voyer et al. (1975) reported that the long term exposure of aquatic organisms to pollutant are more significant in comparison to tests of short duration. Organs of the fish like gill, liver, digestiv tract and olfactory rosette are known to be seriously damaged both structurally and functionally under prolonged exposure

to even low sub-lethal doses of heavy metals (Baker, 1969; Gardner, 1975). Kleerekoper et al. (1973) revealed that pattern of orientation and locomotion of fishes can be modified by low sub-lethal doses of heavy metals like copper. Further Hidaka (1970) and Hidaka & Yakota (1969) observed that heavy metals block the function of Chemo-receptors in few seconds by causing physical injury or functional impairment.

In the wake of all these facts it was thought worthwhile to take up a detailed work on the effects produced by copper sulphate on the olfactory organs, and liver of two exotic fishes namely Carassius auratus auratus (L) and Mollenesia Sp. The object of this study is to determine the effects of lethal and sub-lethal doses of copper sulphate, a very common pollutant used in drinking water and textile industry, on the olfactory rosette and liver, which play a vital role in the sensation and detoxification respectively. Besides this, the author also studied the morphology, and histology of the aforesaid organs of fishes under present investigation. The present work embodies a part of the detai investigation which is only required for the award of M.Phil. degree of this University.

HISTORICAL REVIEW

Olfactory Organs

Bateson (1889) described four types of olfactory folds based on the arrangement of plates (1) in cartilagenous fishes (Skate and dog fishes) the plates are radiating in hollow capsule (2) In conger and eels, plates are folded on both sides of central raphe (3) The plates in flat fishes are arranged in one row lying longitudinally to body axis (4) The arrangement of plates are found in a radiating manner on central raphe.

On the basis of morphological characters Burne (1909) classified the rosettes, nostril and nasal sac in three different types (i) oval (ii) Rounded (iii) Elongated. Further he described types of rosette according to behavioural responses to the olfactory stimulation (i) Rosette with only a few lamellae which shows little responses (microsmates) (2) large rosette with greater number of lamellae (macrosmates) showing well developed sense of olfaction. The oval rosette is generally found in most of the fishes and stands intermediate between the two.

Tiechman (1954) distinguished three types of rosette depending upon the relative development of optic and olfactory faculties. (1) Eye fishes which have better developed eye

than the olfactory organs (*Phoxinus* and *gobio*) (2) Eye-nose fishes with more or less equally developed optic and olfactory faculties (3) Nose fishes bear relatively better developed olfactory organs than optic faculties.

KleereKoper (1969) reviewed the litrature on the anatomy of olfactory organs. Since the first cellular description of Schultz (1856) which he categorised in three different types of receptor, supporting and basal cells. Hall (1965) reported several types of arrangement of epithelial cells.

Kapoor & Ojha (1972a, 1973a, 1974) and Ojha & Kapoor (1971a, 1971b, 1972, 1973a, 1973b, 1973c, 1974) described the anatomy of some Indian fishes (*Mastacembelus pancalus*, *Channa punctatus*, *Garra gotyla*, *Wallago attu*, *Labeo rohita*, *Glyptothorax telchitta* and *Sicor rabdophorus*). They also described histology of *Labeo rohita* and *Channa punctatus*.

Electron microscopic studies of olfactory organs in a number of fishes have been done by various workers namely, Bertmar (1972a, 1972b) *Salmo trutta trutta*, Zieske *et al.*(1976) *Xiphophorus hellari*, Yamamoto & Ueda (1977) Salmoniformes & Yamamoto & Ueda (1978b) Cypriniformes, Jhan (1972) and Zieske *et al.* (1976a) studied the development of olfactory organs in cut throat trout and oviparous and viviparous teleosts respectively.

Hara (1975) described various aspects of the olfaction in fishes and classified them into macrosmat and microsmat. Doving et al. (1977) classified fishes into 'cyclosmates' and 'isosmates' types depending upon the presence or absence of accessory sacs. The fishes provided with sacs are termed as cyclosmates and the sac-less fishes are known as isosmates. According to Doving et al. (1977) the circulation of water in cyclosmates is carried out by the pumping action of accessory sacs while in isosmates the ciliary action of sensory epithelium is mainly reponsible for water circulation. Rehmani (1979) considering the types proposed by Doving et al. (1977) erected a third type which he termed as 'amphismates', where cilia and sac wall are involved together in the circulation of water through olfactory chamber.

Rehmani & Khan (1977) while studying the functional morphology of olfactory organs of Anabas testudineus revealed the importance of various jaw muscles in the transportation of water through the olfactory chamber. Sharma (1978) studied the anatomy and histology of olfactory organs of Notopterus notopterus and Trichiurus savala and reported former as isosmate and later as cyclosmate fish. There exists a variatie in the number of lamellae with respect to size of fish. Peculerity in the histological findings of N. notopterus is the presence of heavy ciliation on the periphery of each

lamella. Rizvi (1978) carried out her work on the morphology of Coilia dussumeri, Tetradon patoca and Ballistes erythrodon. All the aforesaid fishes bear feebly developed olfactory faculty. Rizvi & Khan (1980) correlating with previous findings further reported that the olfactory rosette of T. patoca is absolutely abolished leaving leaf like projection on the both sides of the head infront of eye orbits.

Rehmani (1979) studied the functional morphology of olfactory organs of three fresh water fishes (Anabas testudineus, Colisa fasciatus and Nandus nandus) and three marine species (Ephippus orbis, Carenax oblongus and Otolithus argentus). Detailed studies on the architectonic pattern have been done by Rehmani (1979) on the olfactory rosette, the olfactory lamellae, the two nasal pore, the accessory sacs, the route of water circulation in the olfactory chamber, histological studies of olfactory rosette and accessory sacs of A. testudineus and C. fasciatus. A peculiar structure is observed in each lamella of A. testudineus which facilitates easy water circulation through the olfactory rosette. Rehmani & Khan (1980) reported histological features and discussed the functional importance of different cell type distribution in the lamellae of A. testudineus.

Liver

Kendall & Hawkin (1975) studied the hepatic morphology and acid phosphatase activity in the liver of Ictalurus punctatus. The liver parenchyma consists of laminae of dual

plated muratium as in other siluroids and unlike other I. punctatus bear dispersed pancreases. Srivastava and Chaurasia (1976) studied Puntius sarabhorius and Rasbora daniconius for occurence and distribution of the pancreases and observed in the form of a compact and dense gland. Hinton & Pool (1976) described the hepatocytes, endothelial cells and Kupffer cells in the liver of I. punctatus. Hosking et al. (1977) studied the structure of the liver of Rainbow trout and observed that liver of this fish differs from the mammalian liver in the absence of Kupffer's cells. Small dense duct type cells were present and they formed a transitional zone by combining with hepatocytes to form canaculi microtubules lying in the vicinity of canaculi. Enlarged liver was found by Pruse et al. (1977) in both controlled and wild Dover sole. Desai (1978) described the liver histology of migratory and non migratory Hilsa ilisha and Hilsa toli respectively during different stages of life cycle. He noticed vacuolisation, pynotic nuclie, deposits of collagen material, arterio sclerosis and necrosis of hepatocytes. Jain & Jain (1980) reported histological details of Mystus savessius and observed large central nucleus in the hepatocytes which are arranged in irregular cords.

Olfactory rosette pathology :-

Gardner & LaRoche (1973) studied copper induced damages to olfactory epithelium of some esturine teleosts. They observed lession of olfactory surface due to exposure to heavy metals. Gardner et al. (1975) described the changes which occured due to the application of particular metal. Recently DiMichel and Taylor (1978) reported that toxicity of Naphthaline to the sensory tissue of Fundulus hetroclitus is due to its primary effects on the blood composition. Further they pointed out that damages to sensory epithelium are less in extent in comparison to other organs such as liver and kidney.

Liver Pathology :

Malevski et al. (1974) reported that fishes show inability to develop resistance to liver damage caused by cyclopropenoid acid. They reported several types of injury and recovery after histological analysis of the liver. Bhattacharya (1975) revealed that there is a positive correlation between concentration of endrine and changes in hepatopancrease of Clarias batrachus. Degenerative changes are characterised by the liver cord disarry, vacuolisation and necrosis. Hawkes (1976) studied histological dameges to liver due to exposure to petroleum.

Sovenson (1976) discussed ultra-structural changes in hepatocytes of Leponis cynellus when exposed to sodium arsenate and pointed out the occurance of electron dense particles and increased endoplasmic reticulum. Hecking et al. (1977) studied ultra-structural modifications in the liver of the Rainbow trout after chronic exposure of Polychlorinated biphenyle Arochlor '1254'. They observed changes in the endoplasmic reticulum, increased lysosome; reduced glycogen and increased vacuoles. Koyama & Itazawa (1977) reported accumulation of abnormal black granules in the fish liver due to oral administration of cadmium. Kendall (1977) described acute effects of methyl mercury toxicity in I. punctatus. These are depositions of mercury in liver. Kendall (1977) further observed the accumulation and concentration of mercury in liver and inflamation of hepatocytes. Amminkutty & Rege (1977) described effects of Thiodon '35' and Agallol '3', both acute and chronic on the liver of Gymnocorymbus ternetzi. They reported the destruction of hepatocytes due to chronic treatment. Dimichele & Taylore (1978) studied histopathological responses of Fundulus hetroclitus to Naphthaline and found major effects in brain, liver and pancreas and revealed that the Naphthaline toxicity mainly effects the blood composition.

Dubale & Shah (1979) observed that the malathion is hepato-toxic and induced gradual disintregration of blood tissue and bile material in the liver of Channa punctatus. Nasrain et al. (1980) described under electron microscope, the hepatic cells and renal tissue of some fresh water fishes which were exposed to pollutional stress and observed many lysosomal vesicles and electron dense bodies within the sinusoids followed by increased macrophagal activity. The hepatocytes demonstrated small nuclie and vacuolated cytoplasm. The hyaline bodies of various shapes and sizes are also observed in the vacuoles.

Systematic position and diagnostic characters of *Carassius auratus auratus* (L)

Carassius auratus auratus an exotic fish, is popularly known as gold fish or silver Crucian carp which is domesticated asiatic sub-species of *Carassius auratus auratus* and is found in eastern and central Europe. The gold fishes were first imported to portugal (Sterba, 1962) in seventeen century and after successful breeding, in Holland in 1728, these fishes became well acclimatised in all temperate waters including India.

Linneus (1758) (vide Sterba, 1962) described the genus *Carassius*. Nikolskii (1954) followed Berg (1940) and placed in the sub-family Cyprininae of the family Cyprinidae of order Cypriniformis. Later Sterba (1962) placed genus *Carassius* in family Cyprinidae of sub-order Cyprinoidea and order Ostriophysi. This sub-family Cipprininae (Berg, 1940) is represented by the two genera, the Crucian carp *Carassius* and the wild carp *Cyprinus*.

The genus *Carassius* includes two species; the common Crucian carp- *Carassius carassius* (L.) and silver crucian carp *Carassius auratus* (L.). The silver crucian carp forms two sub-species *Carassius auratus auratus* (L.) and *Carassius auratus gibelio* (Bloch). Various types of *Carassius auratus auratus* are identified. The important ones which are popularly

known as veitail, comet, egg fish and lion head. Among all these variates vietail is most common and beautiful.

C. auratus auratus are dark brown; some greenish tints on the back; golden on sides and yellow on the belly; paired fins are generally red gold to yellowish. They are devoid of barbles and usually have twenty five to thirty one scales along lateral line with a large spine at the front of anal fin and one in front of dorsal fin. C. auratus auratus possesses a long intestine with black peritoneus and the fish can grow upto 45 cm.

Carassius auratus auratus is a delicate fish and commonly thrives in reservoirs with sufficient planting and aeration. They are omnivorous, but besides animal food and detritus, the lower water plants and chironimid larvae are favourite food. These fishes are important owing to their rapid growth rate. Optimum temperature is 40-80°F.

Mollienesia Sp.

They are commonly known as black mollies having black varieties which are generally hybrids of different species of the genus Mollienesia, e.g. M. velifera, M. latipinna and M. sphenops. Sterba (1962) reported that the hybrids are comparatively smaller in size than parents. Mollienesia Sp.

are inhabitants of low land waters of south Carolina to Mexico, but now fully adapted to Temperate and sub-temperate waters. They are Warmth living fishes and prefer temperature between 24 to 28°C.

Nikolskii (1954) followed Berg (1940) described the genus Mollienesia under super family poiciloidea of sub-order Cyprinodontoidei of order Cyprinidontiformes. Sterba (1962) placed genus Mollienesia Sp. in the family Cyprinodontidae of order microcyprini. Mollienesia Sp. prefers plant food together with animal food like insect larvae and are surface feeders. According to Sterba (1962) these viviparous, toothed carps, show sexual dismorphic characters in the anal fin forming gonopodium in males.

MATERIAL AND METHODS

The living specimens of *G. auratus auratus* (L) and *Molliensia* Sp. were purchased from Delhi aquarist. The *G. auratus auratus* and *Molliensia* Sp. range from 25 to 55 mm. and 25 to 34 mm. in length respectively. The fishes were preserved in formaldehyde solution (3.6%).

The head regions of the fishes were dissected from dorsal side under stereoscopic binocular microscope for the study of olfactory organs and their relationship with the brain. The area of olfactory lamellae was measured by the planometer for calculating the olfactory and retinal areas of the fish (Tiechman, 1954). The microscopic measurements of different parts has been taken by the occulometer. After removing scales and skin of the skull region, the fishes were kept in the 4% KOH for 2-3 days subsequently the muscles were removed with the help of brush and forceps. The cleaning and bleaching were done by hydrogen peroxide. Alizarine transparencies of few specimens were prepared by Hollister's technique (1932).

For the investigation of the histological changes to different organs, the fishes were reared in well aerated glass aquaria, and acclimatized to tape water medium for two weeks before the commencement of the experiment. The pollutant used was copper sulphate ($CuSO_4 \cdot 5H_2O$, M.W. 249.68).

The solutions were prepared in well aerated and dechlorinated tape water and their concentrations were .01 ppm and .001 ppm. The temperature of experimental media was 23±3°C. For the test of acute toxicity, fishes were introduced into .01 ppm solution and after 24 h exposure to experimental solution all fishes were taken out. For chronic toxicity fishes were kept for 25 days in experimental media and were regularly fed on commercial fish food obtained from aquaria dealers. The water was changed every 24 h to maintain the concentration of the copper sulphate constant during the period of experiment.

For usual histological observations, the fishes were sacrificed and organs were dissected out for immediate fixation. For the microscopic preparations normal microtechnic procedure was followed using Bouin's fluids as the fixative, paraffin for embedding, Ehrlich's hematoxylene and eosin as stains and DPX as mounter. 6-8 u thick sections were cut.

OBSERVATIONS

Olfactory organs of C. serratus serratus :

C. serratus serratus has a pair of well developed olfactory organs on the antero-dorso-lateral position of the eye slightly away from the snout (Plate 1). Each olfactory chamber (OLF.CHAM) communicates out side by an anterior and posterior nasal apertures. The former is rounded while the latter becomes oval and non valvular. The anterior nasal pore bears a small circular rim. In between the two nasal pores, a fleshy textured and rectangular flap (OLF.FP) is present which separates the olfactory chamber from anterior (ANT.NAS PORE) and posterior nasal openings (POST.NAS.PORE). The rim of anterior nasal pore does not from any tube. Large number of chromatophores are seen on the skin of olfactory chamber and nasal flap.

Each olfactory chamber is oval and the olfactory rosette occupies almost the entire area of the chamber (Plate 2). The anterior nasal pore lies just infront of the raphe (RP) while posterior is above the posterior tip of rosette. Each olfactory rosette is oval in shape, lodged in olfactory chamber and gets connected ventrally to fibrous connective tissue. Its surface is differentiated into ventral convex and dorsal concave. Rosette bears a raphe and

lamellae (OLF.LE) which are arranged in radiating fashion leaving in solitude an individual lamella (Plate 3). The lamellae are well developed with distinct inter-lamellar space in between the two adjacent lamellae. The thick and broad raphe traverses antero-posteriorly between the lamellae of both sides. The oval shaped lamellae of C. auratus auratus are concave dorsally and convex ventrally. They become narrow proximally but get distally broadened. The raphe gets attached with the proximal processes of the lamellae and distally get joined to the wall of the olfactory chamber but become gradually broad at their distal ends. The dorsal surface of each lamella protrudes out distally in the form of a linguiform process. The lamellae lying anteriorly are smaller as compared to the posterior ones. The size of lamellae increases antero-posteriorly suggesting that the growth occured from anterior to posterior direction.

Dissection of head from dorsal side reveals topographical attachment of olfactory rosette (OLF.RE) with the brain (Plate 3). The olfactory bulbs (OLF.BL) are round in shape and are moderately developed. They are of sessile types because they are compactly attached to the olfactory lobes (OLF.LO). The paired olfactory nerves (OLF.N.) are thick and short originating from the corresponding olfactory bulb and unite with olfactory rosette on its anterior side.

The olfactory lobes are well developed and closely attached to the enormously developed optic lobes (OP.LO).

The olfactory pit lies on lateral ethmoid (LETH) bone which is supported dorsally by palatine and ventero-posteriorly by lacrymal (LAC) and prefrontals (PRE.FRONT). Ventrally, the chamber is bounded by inpaired mesoethmoid (Plate 4). The maxilla (MAX) is present at the anterior extremity of olfactory chamber where frontal (FRON) supports the posterior extremity of the olfactory grooves. The olfactory nerve runs along parasphenoid bone (PS.).

To find out the route of water current in olfactory chamber insoluble carmine particles are put at the anterior aperture. At the time of protrusion of jaws rapid rush of carmine particles is seen entering into olfactory chamber through anterior aperture and coming out subsequently from the posterior aperture at the time of retraction (Place 5). The movement of water through olfactory chamber is brought about by the normal breathing of the fish and by the ciliary action of the supporting cells. G. auratus auratus possesses a protrusible mouth which causes increase in the volume of olfactory chamber facilitating the entry of water through anterior nasal pore. At the same time jaw movement also

[illegible] of the floor of the olfactory chamber which enables rosette to get completely bathed by water current.

The ecological coefficient is calculated so as to determine the relative development of olfactory faculty in relation to optic faculty. The results computed (Table I) show that the olfactory area is much larger than retinal area and so this fish be placed under macrosmate group of fishes.

Plate - 1. Lateral view of head of C. auratus auratus

ANT. NAS. PORE - Anterior nasal pore

POST. NAS. PORE- Posterior nasal pore

OLF. FP. - Olfactory flap.

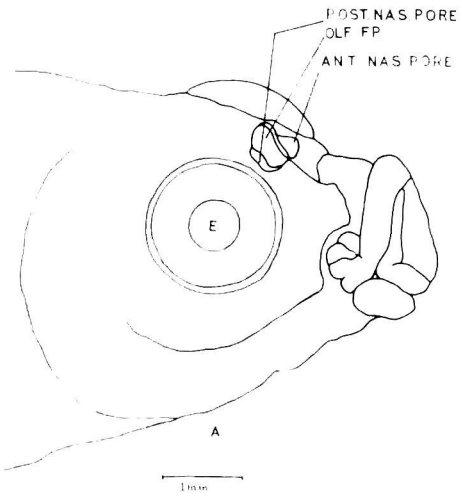

POST NAS PORE
OLF FP
ANT NAS PORE
E
A
1mm

Plate - 2. Rosette of C. auratus auratus in situ.

OLF. RE. - Olfactory rosette.

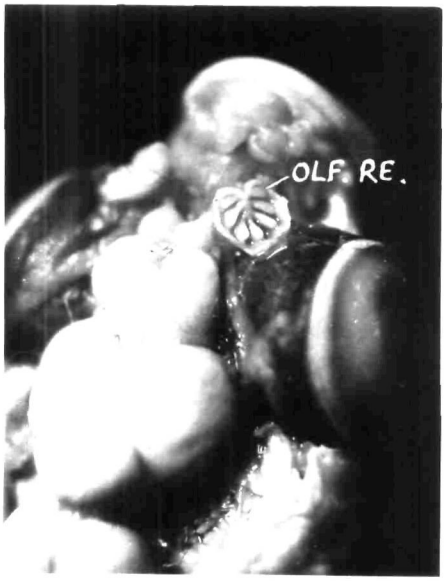

OLF. RE.

Plate - 3a- (B) - Lateral views of nasal pores.

ANT. NAS. PORE - Anterior nasal pore

POST NAS. PORE - Posterior nasal pore.

(C) Diagram of olfactory rosette

OLF. CHAM - Olfactory chamber

RP. - Raphe

OLF. LE. - Olfactory lamella

(D) Diagrammatic representation of the lamellae of right rosette.

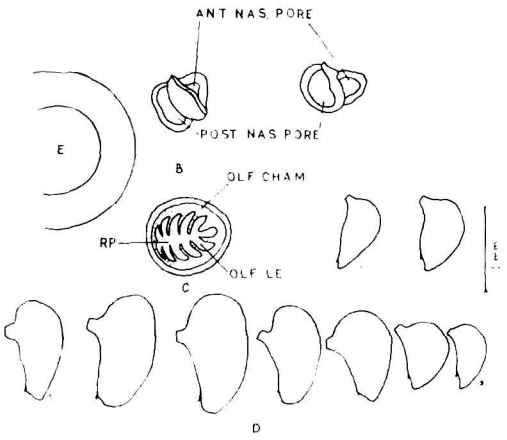

ANT NAS. PORE
POST NAS PORE
E
B
OLF CHAM
RP
OLF LE
C
D

Plate - 3b. Diagram of the brain of C. *auratus auratus* from the dorsal side to show the relationship of the brain with the olfactory rosette.

CE. - Cerebellum
E. - Eye
OLF. BL. - Olfactory bulb.
OLF. LO. - Olfactory lobe.
OLF. N. - Olfactory nerve.
OLF. RE. - Olfactory rosette.
OP. LO. - Optic lobe.

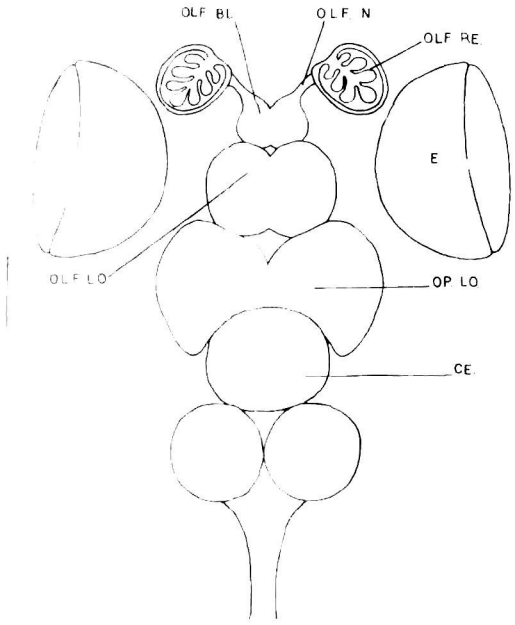

OLF BL
OLF N
OLF RE
E
OLF LO
OP LO
CE

Plate - 4. Lateral view of skull of C. auratus auratus showing the position of olfactory rosette.

ART. - Articular
ANG. - Angular
BRSTG - Branchiostegial
DEN. - Dentary.
DSPH. - Dermsphenoid.
ENT. - Enteropterygoid
FRONT - Frontal
HYO. - Hyomandibular
IOP. - Inter operoular
LAC. - Lacrymal
MAX. - Maxilla
MPT. - Metapterygoid
NAS. - Nasal
OLF. CHAM. - Olfactory chamber
OS. - Orbitosphenoid
OP. - Operoular
PRE. OP. - Pre operoular
PRE. F. - Pre frontal
PRE. MAX - Pre maxilla
PA. - Parietal
PS. - Parasphenoid
PTR. - Pterygoid
QUAD - Quadrate
SUB. OR. - Sub orbital
SOP. - Supra orbital

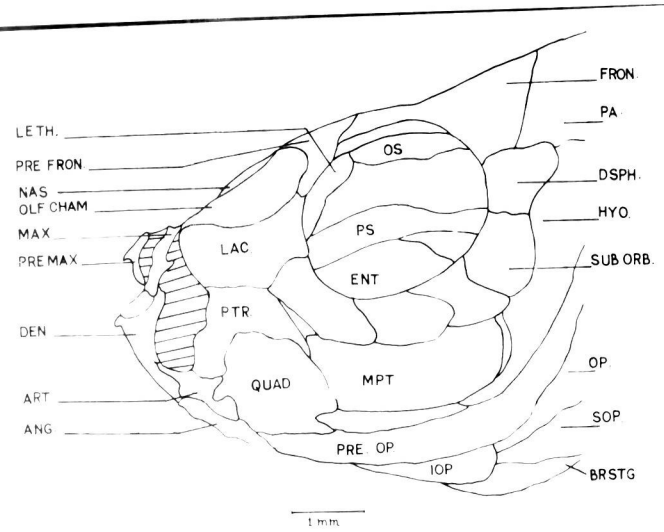

LETH.
PRE FRON.
NAS
OLF CHAM
MAX
PRE MAX
DEN
ART
ANG
FRON.
PA.
OS
DSPH.
HYO.
PS
LAC
SUB ORB.
ENT
PTR
OP.
QUAD
MPT
SOP
PRE OP.
IOP
BRSTG
1 mm

Plate -5. Diagram showing the olfactory chamber of *C. auratus auratus*. Arrows indicate probable route of water circulation.

ANT. NAS. PORE. - Anterior nasal pore
OLF. FP. - Olfactory flap.
OLF. RE. - Olfactory rosette.
OLF. CHAM. - Olfactory chamber
POST. NAS. PORE. - Posterior nasal pore.

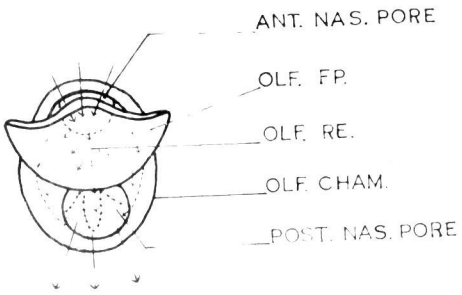

ANT. NAS. PORE
OLF. FP.
OLF. RE.
OLF. CHAM.
POST. NAS. PORE

Table - I C. auratus auratus

Sl. No.	Standard length	Total length	Number of lamellae Rosette		Length of Mesen-cephalon	Length of Telence phalon	Ecological coefficient through brain lobes Length of Telen. / Length of Mese. x100	Retinal area of eye	Olfactory area of both rosette	Ecological co-efficient olfactory area / retinal area x 100
			Right	Left						
1.	32	55	9	9	1.755	1.989	113.40	6.76	47.0	352.85
2.	30	49	7	7	1.638	1.872	114.28	5.673	38.6	344.64
3.	21	38	7	7	1.304	1.755	134.58	4.29	16.18 x 2 = 32.36	377.00
4.	29	35	7	7	1.404	1.638	116.66	4.736	53.62	333.00
5.	21	38	7	7	1.404	1.872	133.33	4.29	16.81	391.84

Olfactory organs of Mollienesia Sp.:-

A pair of olfactory chamber (OLF.CHAM) lies on the antero-dorso-lateral side and each chamber communicates out side by an anterior and posterior apertures (Plate 6). The former is tubular projecting externally in the form of broad circular tube while latter is non-tubular and non-valvular lying on the surface of intergument. Anterior nasal tube is present on the extremity of the snout. The anterior aperture (ANT.NAS.PORE) is elliptical while posterior (POST.NAS.PORE) gets inwardly curved. The former rests on a tube. The chromatophores (CHR) are numerous which lie scattered on the entire olfactory chamber leaving the border of nasal pores.

After removing carefully the muscles and the bony components of the cranial vault leads to the exposition of the olfactory rosette and brain of the fish (Plate 7). Each olfactory chamber is triangular in shape. The olfactory rosette occupies almost the entire chamber (Plate 8). Dorsally and dorso-laterally the olfactory rosette appears to be slit like and triangular respectively. The lamellae are wanting in the rosette. The entire rosette under high magnification shows numerous patches or areas which are formed by the lining of the connective tissue.

The rosette and olfactory bulb get joined by the olfactory nerve (OLF.N.) but olfactory bulb (OLF.BL.) and olfactory lobe (OLF.LO) are directly attached with one another

showing sessile condition. Each olfactory nerve traverses through tunnel lying in the pre-frontal-lateral ethmoid and then joins with the olfactory bulb traversing through parasphenoid and dermasphenoid. The olfactory lobes get enormously enlarged and lie in front of the optic lobes (OP.LO).

The olfactory pit is formed by the lacrymal; lateral ethmoid (LETH); a part of parasphenoid (PS) and supra-orbital (SUP.ORB.) cranial components. The frontal (FRO) and pre-frontal (PREFRO.) dorso-laterally and maxilla (MAX.) anteriorly contribute to form the olfactory pit (Plate 9). The roof and the floor of the olfactory pit is formed by the nasal; palatine and anterior extension of the parasphenoid (PS.) When kinematics of jaw movement is considered, it was found that the olfactory chamber shows variation in relation to jaw movement. This involves the movement of the ethmoid and lacrymal along with slight elevation of palatine bones. When carmine particles are placed on the anterior pore they then reach into the olfactory chamber where they get circulated over the rosette by means of cilia and then pass out through the posterior nasal pore. Mallogaster Sp. is an isosmate where cilia are involved in the circulation (Plate 10).

The ecological coefficient values when obtained after calculating areas of both retinae and olfactory rosette (Table II) it was found that the area of retinae is higher than that of olfactory rosette placing this fish under microsmat type

Plate- 6. (A)- Lateral view of head of Mollienesia Sp.

ANT. NAS. PORE. - Anterior nasal pore.

POST. NAS. PORE - Posterior nasal pore.

(B) Lateral view of Anterior nasal tube and posterior pore.

ANT. NAS. PORE - Anterior nasal pore.

POST. NAS. PORE - Posterior nasal pore.

E. - Eye.

CHR. - Chromatophores.

(C) Diagram of olfactory rosette.

OLF. C[illegible]. - Olfactory chamber.

OLF. RE. - Olfactory rosette.

Plate -7. Diagram of the brain of Hollienesia Sp. from dorsal side to show the relationship of brain with the olfactory rosette.

CE. - Cerebellum.
E. - Eye.
OLF. BL. - Olfactory bulb.
OLF. LO. - Olfactory lobe.
OLF. N. - Olfactory nerve.
OLF. RE. - Olfactory rosette.
OP. LO. - Optic lobe.

Plate - 8. Rosette of Mollienesia Sp. in situ.

OLF. RE. - Olfactory rosette.


OLF. RE.

Plate - 9. Lateral view of skull of Mollienesia Sp. showing the position of olfactory rosette.

ART. - Articular.
ANG. - Angular.
DEN. - Dentary.
DSPH. - Dermsphenoid.
ETH. - Ethmoid.
LETH. - Lateral ethmoid.
FRONT.- Frontal.
HYO. - Hyomandibular.
MAX. - Maxilla.
MPT. - Metapterygoid.
OLF. CHAM. - Olfactory chamber.
PRE. OP. - Pre opercular.
PRE. FRON. - Pre frontal.
PRE. MAX. - Pre maxilla.
PA. - Parietal.
PS. - Parasphenoid.
PTR. - Pterygoid.
QUAD. - Quadrate.
SUB. ORB. - Sub orbital.

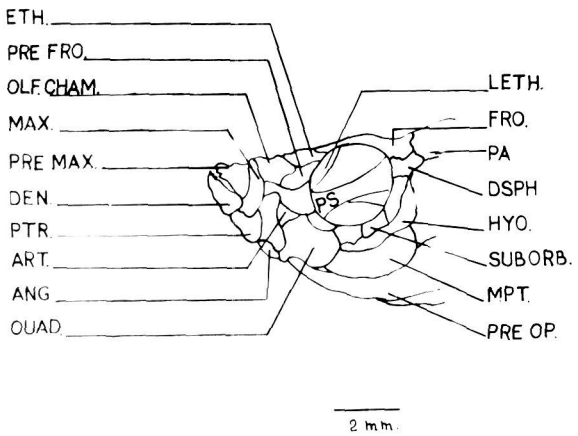

ETH.
PRE FRO.
OLF. CHAM.
MAX.
PRE MAX.
DEN.
PTR.
ART.
ANG.
QUAD.
LETH.
FRO.
PA
DSPH
HYO.
SUBORB.
MPT.
PRE OP.
PS
2 mm.

Plate - 10. Diagram showing the olfactory chamber of Mollienesia Sp. Arrows indicate probable route of water circulation.

ANT. NAS. PORE - Anterior nasal pore.
ANT. NAS. TUBE - Anterior nasal tube.
OLF. RE. - Olfactory rosette.
OLF. CHAM. - Olfactory chamber.
POST. NAS. PORE - Posterior nasal pore.

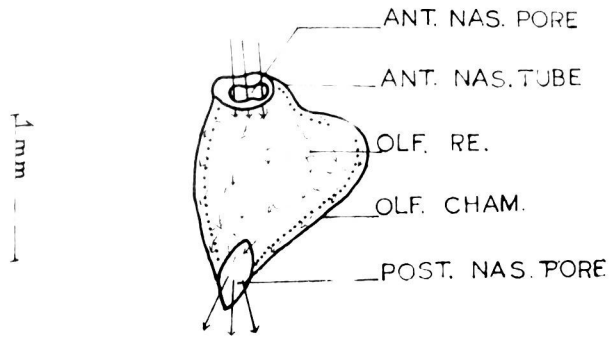

ANT. NAS. PORE
ANT. NAS. TUBE
OLF. RE.
OLF. CHAM.
POST. NAS. PORE
1 mm

Table - II Mollienesia Sp.

Sl. No.	Standard lengthof fish (mm)	Total length of fish (mm)	Length of Mesence-phalon (mm)	Length of Telence-phalon (mm)	Ecological coeffi-cient through lobe of brain $\frac{\text{Length of Telence-phalon}}{\text{Length of Mesen-phalon}} \times 100$	Retinal area of both rosette (mm^2)	Olfactory area of both rosette $(mm)^2$	Ecological coefficient $\frac{\text{Olfactory area}}{\text{Retinal are}} \times 100$
1.	31	37	1.287	1.053	81.81	6.96	1.622	25.21
2.	34	40	1.404	1.170	83.33	8.59	2.183	23.30
3.	25	30	1.170	1.053	90.00	5.50	1.387	25.21
4.	25	30	1.053	0.936	88.88	5.50	1.364	25.19

The histology of olfactory organs of C. auratus auratus :-

In C. auratus auratus each lamella splits into a central core or submucosa and peripheral zone. The central core is composed mainly of reticular and collagen connective tissues. The peripheral zone or mucosa consists of pseudostratified columnar and ciliated epithelium. A basement membrane separates the central core from mucosal layer. Below the sensory epithelium lies a few cell layer loose basal zone. (Plate - 11 & 12)

Cells of the olfactory lamella :- The olfactory epithelium consists of supporting or sustentecular cells, receptor cells or neurons, basal cells and goblet or mucous cells. The receptor and supporting cells get arranged in groups similar to those of taste buds.

The supporting cells :- Two types of supporting cells are distinguished - ciliated and non-ciliated. Each supporting cell possesses a large nucleus with clearly visible nucleolus and chromatin material. The nuclei of supporting cells lie at the lower half of the cell. The large and columnar distal ends of supporting cells reach the superficial surface and the cilia are given out through the basal bodies on the peripheral layer of the cell. The ciliated supporting cells are more common and occupy alternate position with respect to receptor cells.

The receptor cells :- The non-ciliated receptor cells bear rounded nuclie lying in the lower half of the cells. The

dendrites of the receptor cells reach upto free surface. Few axons of adjacent receptor cells join together and form folium olfactorium. This extends above the basal membrane to join the non-medulated nerve at the raphe.

The goblet cells :- These are intercepted in the epithelial layer. These mucous secreting unicellular cells vary in size and open at epithelial linings. These cells lie scattered basally with flattened nuclei.

The basal cells :- They are numerous and lie in between basement membrane and lower portion of mucosa. They bear minute nuclei which are not arranged in group and also show division.

The submucosa or central core :- The submucosa gets separated by well defined basement membrane. It consists of collagen and connective tissue. Nerve fibres, blood vessels, fibroblasts and lymphatic cells are also seen.

Plate - 11. Vertical section of the olfactory lamella of *O. auratus auratus* x 400

BA. M. - Basal membrane.
CON. T. - Connective tissue.
CL. - Cilia.
CE. CO. - Central core.
G. - Goblet cell.
RC. C. - Receptor cell.
SUP. C. - Supporting cell.
SUP. Z. - Supporting zone.
SEN. Z. - Sensory zone.

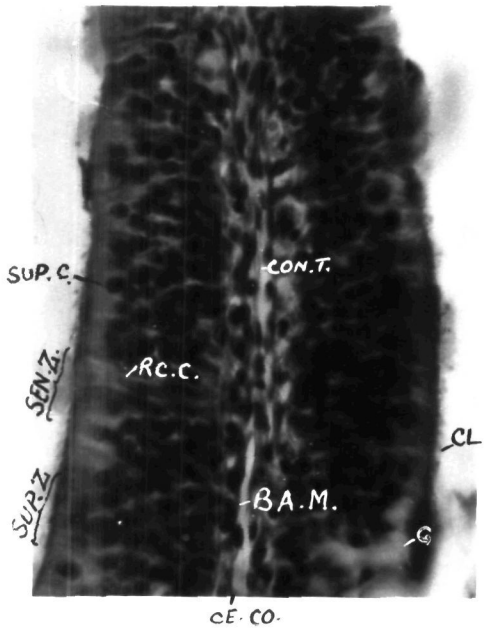
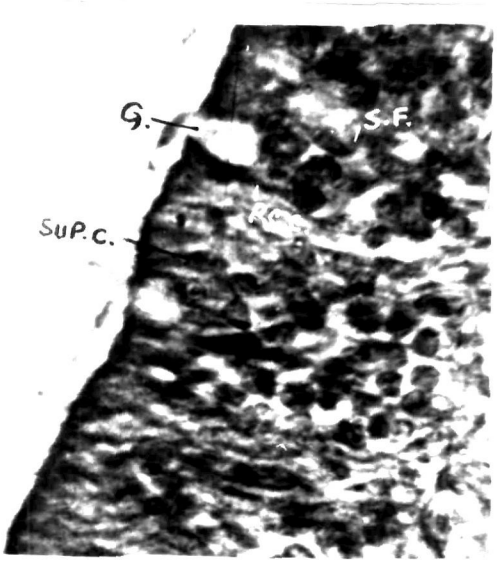

SUP. C.
CON. T.
SEN. Z.
RC. C.
CL
SUP. Z.
BA. M.
G
CE. CO.

Plate - 12. Details of olfactory lamella of *C. auratus auratus* x 4000

G. - Goblet cell.
RC. C. - Receptor cell.
SUP. C. - Supporting cell.
S.F. - Sensory fibre.


G.
S.F.
SUP.C.

Histology of the Liver of G. serratus serratus :-

The main hepatic structure includes liver parenchyma and blood vessels. The parenchymatus cells forming cords lie irregularly and get separated by blood channels. The liver cells are polyhydral in shape with prominent peripheral lining. Each cells bears a central nucleus with clear nuclear membrane. Some hepatic cells are binucleate. The hepatic sinusoids are present in between hepatic cords. Each sinusoid consists of an outer peripheral connective tissue and an inner lining of endothelial cells. (Plate - 15)

Histology of liver of Mollienesia Sp. :-

The hepatic parenchyma of Mollienesia Sp. consists of continuous masses of cells forming cords. Blood sinusoids lying frequently between hepatic cords are lined by endothelial cells. They also get covered by connective tissue. A single sinusoid often joins with the other by transverse connection. Polyhydral hepatocytes with a well defined cell membrane bears a well defined centrally located nucleus with dense cytoplasm. Portal veins get surrounded by the exocrine pancreas to represent a diffused pancreas. The large pancreatic cells with dark stain are also seen. (Plate - 16)

Plate - 15. Liver tissue from control fish
(*C. auratus auratus*) x 400

CV. - Central vein.
HT. - Hepatic tissue.
S. - Sinusoids.

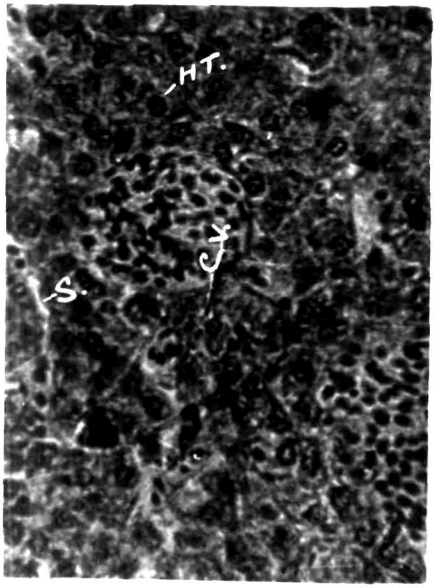
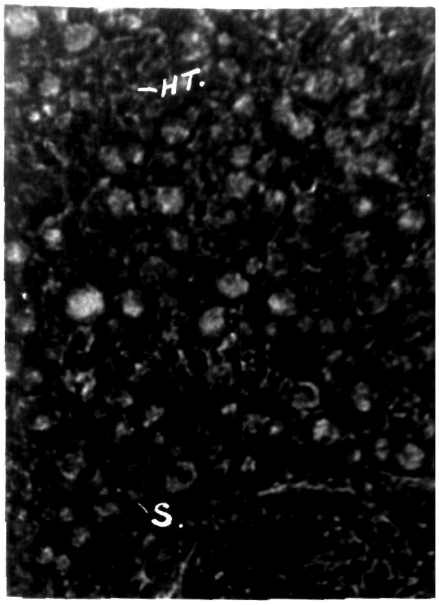

HT.
S.

Plate - 16. Liver tissue from control fish (Mollienesia Sp.) x 400

HT. - Hepatic tissue.

S. - Sinusoids.


—HT.
S.

Histopathology of olfactory organs of C. auratus auratus :-

Fish exposed to .01 ppm Copper sulphate :

The olfactory epithelium gets inflamated. The entire olfactory rosette is covered by the thick layer of mucous. The goblet cells undergo swolling. (Plate - 13)

Fish exposed to .001 ppm Copper sulphate :-

The mucous cells get shrinked due to excess mucous secretion. Some of the epithelial cells show intense vacuolization, and lead to disruption in the cytoplasm. The matrix of medullary zone undergoes swolling with dilated blood vessels. (Plate - 14)

Plate - 13. Olfactory lamella from fish (G. *curatus curatus*) subjected to .01 ppm copper sulphate x 400

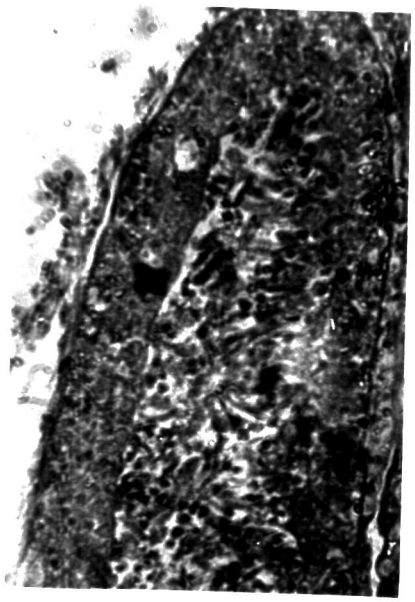
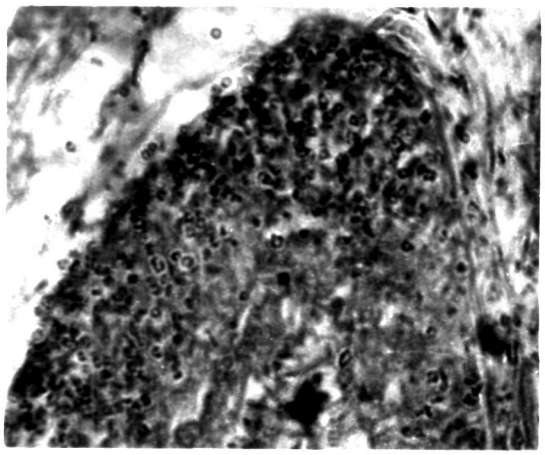


Plate - 14. Olfactory lamella from fish (C. auratus auratus) subjected to .001 ppm copper sulphate x 400



Histopathology of liver of C. auratus auratus :-

Fish exposed to .01 ppm Copper sulphate :-

Specimens exposed to acute concentration of copper sulphate show effects of toxicity on the liver of A. C. auratus auratus. Architectural deformation is observed due to the inflamation. The hepatocytes show partial vacuolization due to the precipitation of cytoplasm which accumulates in the granular material. The nuclei of hepatic cells become swollen and appear to be pynotic. The sinusoids also undergo degeneration. (Plate - 17)

Fish exposed to .001 ppm Copper sulphate :-

The changes here appear to be more prominent. Some of the hepatocytes become completely and some become partially vacuolated. The nuclei migrate towards the periphery of cells. The migratory activity is due to the result of precipitation of the cytoplasm leading to vacuolization. Some nuclei bear dense particles with less clear nucleoli in the granular material. The cells in the neighbourhood of the sinusoids are more prone to disintergration. The spaces of blood sinusoids do not fill the entire cavity suggesting the decreased blood supply. (Plate - 18)

Plate - 17. Liver tissue from fish (C. *muratus muratus*) subjected to .01 ppm copper sulphate .x 400

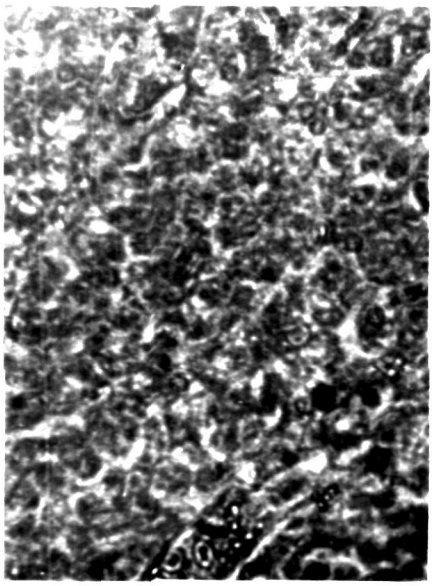


Plate - 18. Liver tissue from fish (C. auratus auratus) subjected to .001 ppm copper sulphate x 400

Histopathology of liver of Mollienesia Sp.

Fish exposed to .01 ppm Copper sulphate :-

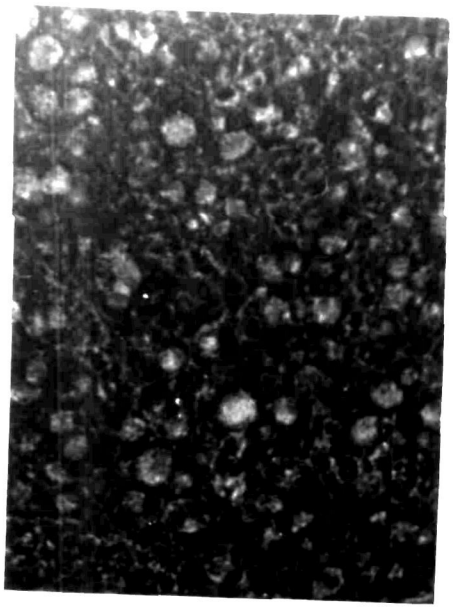
The liver of Mollienesia Sp. when exposed to acute level of copper salt concentration the following diagnostic changes have been observed.

The hepatocytes undergo swelling with condensed cytoplasm. The portal vein shows coagulation of blood. The pancreatic acinar cells lying in the vicinity of the veins become more effected than those of the hepatocytes. The cordal arrangement seems to be crumpled due to swollen and stretched hepatocytes. The nuclei of hepatocytes become large. The delectrous effect appears due to the accumulation of coagulated blood which gets dark stained.(Plate - 19)

Fish exposed to .001 ppm Copper sulphate :-

The vacuolisation of hepatocytes causes serious effects which result in the total disruption of hepatic cords. Some of hepatocytes become completely while others are partially vacuolated. This leads to the forced shifting of nuclei towards periphery and may, therefore, be due to the precipitation of the cytoplasm. Nuclei get shrinked. The sinusoids also undergo disintegration. The hepatocytes in the neighbourhood of the sinusoids are liable to more toxic hazards than the central ones (Plate - 20)

Plate - 19. Liver tissue from fish (Mollienesia Sp.)
subjected to .01 ppm copper sulphate x 400



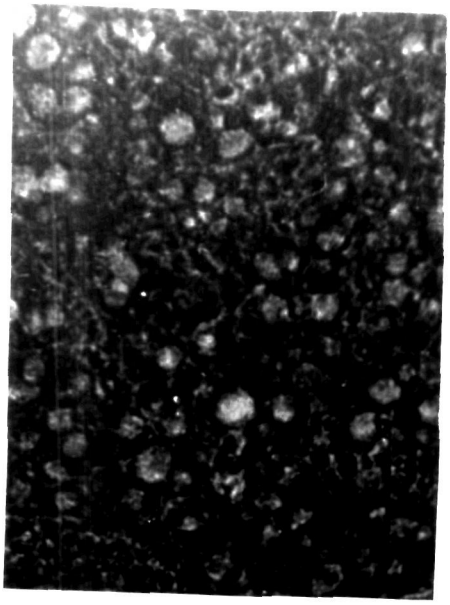
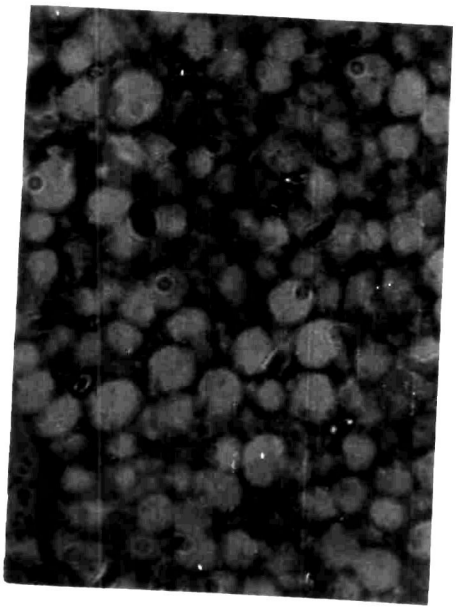


Plate - 20. Liver tissue from fish (Mollienesia Sp.) subjected to .001 ppm copper sulphatex 400



DISCUSSION

The paired olfactory chambers of G. [redacted] are enclosed in the ethmo-palato-maxillary complex and are also supported by the lacrymal and frontal dorso-laterally and maxilla anteriorly. In Mollienesia Sp., the floor of the olfactory chamber is formed by ethmoid while the remaining parts of the chamber are supported dorso-laterally and antero-posteriorly by palatine and lacrymal; maxilla and prefrontal respectively. In G. suratus suratus olfactory chamber lies dorso-laterally in front of eyes while in Mollienesia Sp. it gets shifted laterally. The location of the olfactory chamber is both the fishes under investigation are found to be in line as suggested by Burne (1909). According to him "The olfactory chamber occupies a constant and fixed position with regards to the bones of the skull". Kapoor and Ojha (1972, 1973) and Rehmani and Khan (1977) also reported regarding the location of the olfactory chamber in cyprenoid and siluroid fishes and Anabantoid fish (Anabas testudineus) respectively and agreed with the findings of Burne (1909) but Sharma (1978) reported that the olfactory chamber is formed mainly by palato-ethmoidal complex in [redacted] and Trichirus savala

There are two nasal openings in both Mollienesia Sp. and G. [redacted]. In former the anterior nasal opening is in the form of small nasal tube while latter bears a rim

around the anterior nasal pore and terminates where the flap originates. According to Bateson (1889) and Ojha & Kapoor (1972) the olfactory surface is relatively much more developed in those fishes having tubular anterior opening. The findings of the present author with reference to Mollienesia Sp. do not lend support with the observations of Bateson (1889) and Ojha & Kapoor (1972) because Mollienesia Sp. having tubular opening bears less developed olfactory faculty and be categorised as microsmate. The similar investigations have also been reported by Rehmani (1979) in C. fasciatus and A. punctus. According to Hara (1975) the elongated olfactory chambers are the characteristics of macrosmate fishes where anterior and posterior nasal openings are invariably situated at some distances such as morays and eels.

The oval posterior opening is larger in size than the anterior in C. auratus auratus whereas in Mollienesia Sp. it is eccentric in shape and lies posterior to the olfactory chamber. The size and the shape according to Burne (1909) of posterior nostril very significantly in different species. The presence of a single nostril has been reported by Sharma (1978) in T. mosula. According to him the formation of this nostril is due to the elevation of the olfactory floor disrupting the bridge of the two nostrils. Rizvi and Khan (1980) observed the complete absence of olfactory chamber is T. nahoor but reported the presence of olfactory organs which are

represented by well developed olfactory flaps on either side of head. This is in agreement with the findings of Burne (1909). According to him a cavity may be everted and the organ is transformed to a bifoliate tentacle in Tetradons (Weidersheim and Tate regan). Perception of olfactory sense is received by the hexagonal areas present on the flap which remains in contact with water. This may probably be due to ecological needs rather than of any phylatic significance.

Numerous workers on the shape and size of olfactory rosette have classified the fishes. Bateson (1889) and Burne (1909) hold that oval shaped rosette is most common in fishes. The oval shaped rosette with raphe is present in G. [illegible] and be classified under Bateson (1889) rosette type 3 (Rosette column). The rosette of Mollienesia Sp. is triangular shaped and does not fall in any group as suggested by Bateson (1889) and Burne (1909). The presence of triangular rosette has also been reported in Xiphophorus hillari by Zieske et al. (1976 a). Mollienesia sp. and X. hillari are exclusively surface feeders and thrive in similar habitat. The entire rosette bears irregular sensory areas which get demarcated by non sensory connective tissue.

Tiechman (1954) distinguished the fishes on the basis of optical and olfactory faculties. According to him the fishes having predominently developed sense of olfaction rather than sense of vision are grouped under macrosmates.

G. auratus auratus can be placed under group of macrosmate fishes (2) Fishes with enormously developed sense of vision than that of olfaction be included in microsmate. Mollienesia sp can be grouped under this category. (3) Fishes with equally developed sense of vision and olfaction are grouped under eye-nose fishes. Moreover, Tiechman (1954) suggested that the fishes with oval rosettes be included under eye-nose fishes. The present findings contradict the above generalisation because G. auratus auratus is a macrosmate with a oval rosette. This generalisation of Tiechman (1954) in the author's view seems to be quite immature as he generalised his observations on fewer number of specimens.

G. auratus auratus bears a nasal flap between the anterior and posterior nostrils. The small flap does not cover the entire anterior pore and thus probably helps to reflect water towards the anterior pore. Johnson & Brown (1962) reported similar structure in Sebastodes melanops. The posterior nasal opening of Mollienesia Sp. is devoid of a valve which is generally absent in fishes having tubular anterior openings (Tiechman, 1954; Ojha & Kapoor, 1972).

The rosette of G. auratus auratus possesses a raphe which is a thick up folding of epithelial floor of the chamber and gets innervated by olfactory nerve. Burne (1909) studied 52 genera and reported the presence of raphe in 42 genera.

Branson (1963) termed raphe as central lamella. Rehmani (1979) observed that raphe less fishes have less number of lamellae and according to him "The number of olfactory lammelae become restricted due to absence of raphe and generally but not always - such fishes are microsmate".

G. auratus auratus has nine lamellae (when 32 mm total length) in one rosette. The number of lammellae increases with size of fish. Similar observations were also reported by Tiechman, 1954; Pfieffer, 1963; Kleer Koper, 1969; Doving et al. 1977 and Rehmani, 1979. Pfieffer (1963) observed the increase in the number of lammellae with the growth of the fish and after it their number become constant upto certain extent. Rehmani and Khan (1977) found that there is no correlation between number of lamellae and size of Anabas testudineus. Devitsyena (1972) revealed that number of lamellae remain relatively constant and is a species characteristics. Moreover, he pointed out that increase in receptor surface is due to increased area of individual lamellae and not their number. Rehmani (1979) suggested that addition of further lamellae takes place only in immature specimens for the purpose to increase in surface area of sensory epithelium but after achieving full complement of lamellae the increase in surface area is mainly due to the enlargment of the individual lamella. The inter-lamellar space is kept constant due to the growth of raphe. Doving et al (1977) termed these as 'Thumbs' which occur at dorso-lateral end of lamellae.

The accessory nasal sacs are absent in both the fishes under investigation. Kyle (1899) reported that accessory sacs are present in sedentary and semi sedentary fishes. Bertmar (1969) and Kapoor & Ojha (1972 a) also find an accord with above view and reported that an accessory sac is a necessity to sedentary life. Burne (1909) contradicted the Kyle's (1899) suggestion and concluded that there exists no correlation between accessory sac and the habit of the fish. Further he pointed out that the accessory sac is a structural advancement in those fishes which show advanced trend in their development. Bertmar (1969) observed accessory sacs in primitive actinopterygians and fossil crossopterygians and suggested that sacs are primitive specialization. Rehmani (1979) reported that the presence or absence of accessory sac(s) in fishes could not be explained by ecological or phyletic considerations. He pointed out that the presence of accessory sac(s) depends on the general configuration of the head. Further he pointed out that the presence of accessory sac generally depends on the protrucibility of mouth. But this suggestion is also debatable because C. auratus auratus having protrusible mouth is without accessory sac.

Hara (1975) described three types of nerve attachment in fishes (1) the bulb is closely located to the nose, the olfactory nerve is short and long tract is present (pedunculate) (2) the bulb is closely attached to the

hemisphere of brain so as to form long olfactory nerve (sessile) (3) the position of the bulbis intermediate between nose and brain (intermediate). Both C. auratus auratus and Molliensesia Sp. fall under the second category of Hara (1975). It is suggested that categorisation as proposed by Hara (1975) has therefore, no relevance with regard to macrosmate and microsmate nature of the fishes.

Doving et al. (1977) and Doving & Thomson (1977) reported the mechanism of water circulation in the olfactory chamber. They divided fishes into two groups (i) the water circulation is carried out by ciliary movement of olfactory epithelium (isosmate) (ii) the circulation is carried out mainly by pumping action of accessory sacs synchronously with respiratory movement of operculum (cyclosmate). The fishes under investigation are isosmate types as they do not have accessory sacs and only cilia take part in water circulation. Rehmani (1979) proposed a third type which he termed as amphismates besides cyclosmates and isosmate of Doving et al.(197 Amphismate according to Rehmani (1979) involves participation of both cilia and sac wall for the circulation of water and is found in Anabas testudineus and C. fasciatus.

Unidirectional flow of water i.e. entry from anterior and expulsion from posterior nasal opening, is observed in both C. auratus auratus and Molliensesia Sp. Doving et al. (1977)

also reported unidirectional flow of water but Johnson & Brown (1962) and Kapoor & Ojha (1973a) found that water enters in olfactory chamber through both the openings and is expelled out through posterior opening (Johnson & Brown, 1962) or through both opening (Kapoor & Ojha, 1973a). Rehmani (1979) contradicted the findings of Kapoor & Ojha (1973a) and suggested unidirectional flow of water in olfactory chamber. He described three factors participating (i) Vibratory movement of cilia produces only antero-posterior water current (ii) hinge type of valve in posterior openings when present, restricts the entry of water through this pore (iii) position of accessory sacs causes direct expulsion of water through posterior pore.

The topography of the brain was done to find out relative size of the olfactory bulb, lobes and optic lobes which help to determine the degree of development of olfactory and optical faculties. Davis & Miller (1967) reported the significance of their development reflecting the capacity of these faculties. Tiechman (1954) and Devitsyana (1972) considered ratio of mesencephalon and telencephalon to calculate the ecological coefficient but Rehmani (1979) considered only percentage ratio of both the foregoing parts to find out the ecological coefficient in numerous fishes. The author adopted Rehmani's (1979) modifications over

Tiechman (1954) and Devitsyana (1972) method in the present work. The ecological coefficient when calculated in C. auratus auratus and Mollienesia Sp. was termed to be macrosmat and microsmat respectively.

The structure of olfactory epithelium has been described by various workers (Branson, 1963; Bertmar, 1972a and b; Kapoor & Ojha, 1974; Ojha & Kapoor, 1973; Hara, 1975; Rehmani, 1979 and Rehmani & Khan, 1980). Generally the olfactory lamellae of all fishes possess two layers; a central core or submucosa and outer sensory mucosa. The mucosal layer of C. auratus auratus consists of supporting cells, receptor cells and goblet cells with a proximal lining of basal cells which get separated by a basal membrane from a central core. Both ciliated and non-ciliated supporting cells are present. Former bear prominent cilia while latter are without cilia. The ciliated supporting cells are divisible into cilia bearing distal broad and proximal narrow ends which extends upto the basement membrane. In C. auratus auratus the supporting and receptor cells get arranged in groups. Bertmar (1972a & b) also observed grouping of supporting cells and reported that there is no difference between two types of cells and also have no relevance to olfaction except some nutritional significance. Rehmani & Khan (1980) discussed the functional significance of grouping of different type of cells in A. testudineus. Besides nutritional and complex

secretary function, the cells also help to provide a mechanical support to the existing sensory cells (Bertmar, 1972b) and their cilia help in the circulation of mucus and water (Bertmar, 1972b; Doving & Thomassen, 1977; Doving et al., 1977). The sensory cells bear cilia (Zieske et al., 1976; Yamamoto & Ueda 1977, 1978). The occurence of non ciliated supporting cells in between the ciliated sensory cells are mainly for the purpose to avoid interference in the ciliary movement.

The receptor cells are confined in group. S. Holl (1965) reported three types of distribution of sensory cells (i) continuous except for dorsal part (ii) separated in larger areas between the lamellae (iii) dispersed in small areas. The arrangement of receptor cells in G. auratus auratus is similar to third type. The dendritic supply of receptor cells is formed by neurons which directly unite to form non medulated nerve, such type of axon is also reported by Zieske et al. (1976) and Yamamato & Ueda (1978b). However, Kapoor and Ojha (1972) and Ojha & Kapoor (1973) observed secondary neurons in Channa punctatus and Labeo rohita but Rehmani & Khan (1980) contradicte the presence of secondary neurons in case of Anabas testudineus.

The mucus secretory cells are interspersed among the epithelial cells as observed by Ojha & Kapoor (1973) and Holl (1975). However, several workers (Branson, 1963; Singh, 19 and Rehmani & Khan, 1980) reported their absence in the olfactor epithelium. The basal cells are rounded or oval in shape with small nuclei and lie just above the basal membrane in

C. auratus auratus. These indifferentiated cells may from the receptor cells (Graziadi & Metcalf, 1971) or supporting cells (Gordier, 1964) or both types of cells (Hara, 1975). Ojha & Kapoor (1973) described gradual transformation of basal cells into supporting cells. Rehmani and Khan (1980) also reported aggregation of these cells in A. testudineus at the places where they may give rise to secondary lamellae.

In pollutant treated C. auratus auratus, the mucus cells of olfactory epithelium get shrinked and the epithelial cells show disruption in the cytoplasm due to vacuolization. Kleerekoper (1972, 1973) reported that gold fish responds to sub-lethal doses of copper (11-17 ug / lit) and the degree of damage depends on the steepness of concentration and duration of testu. Gardner et al. (1974) reported that the pathological lessions in the olfactory epithelium are different to each metal. The swollen condition of matrix of medullary zone is seen in C. auratus auratus which is in agreement with the findings of DiMichele and Taylore (1978). According to them the damages to sensory tissue are not solely due to direct contact to toxic substances but also due to the changes in the blood composition. The toxic effects of copper sulphate are lesser in olfactory rosette in comparison to other organs of C. auratus auratus. This is because the fishes when subjected to toxic environment, the rate of respiratory movement decreases and is synchronomous to that of jaw movement. Moreover, the secretion of mucus also forms a barrier with respect to toxic

The fishes under investigation when treated with pollutant show toxic effects on the body organs. As regards hepatic region the lessions in general are characterised by the destruction of the cytoplasmic material of hepatocytes and their consequent vacuolization. A gradual increase in the damages is noticed with larger duration of exposure along with the necrosis of hepatocytes and coagulation of blood in sinusoids. Similar changes are observed by Kendall (1975) in channel cat fish and Malevski et al. (1975) in rainbow trout. The higher extent of damages in hepatocytes lying in the vicinity of sinusoids is probably due to the presence of toxic substances in the incoming blood. Baker (1969) reported that copper initially induces haemolytic anaemia and further changes in liver are secondary effects in the Pseudopleuronectes americanus.

Mukhopadhyaya & Dehadrai (1977) observed increase in the cytochrome, P-450 content due to exposure of Malathion, which is known to be associated with the increase in metabolic activity of Mono-oxygenase system to metabolic exteraneous compounds. This induction of metabolic enzymes may enhance the normal rate of detoxification of exteraneous components. Dalela et al. (1978) reported the decrease in the activity of acid phosphatase in liver at sub-lethal doses of Thiodon. They suggested that their biochemical changes may cause hazard in hepatic region due to the incoupling of phosphorylation following intoxication of pollutant.

SUMMARY

The olfactory chamber in G. auratus auratus and Mollienesia Sp. lie antero-dorso-lateral position with respect to eye. Each olfactory chamber opens outside by an anterior and the posterior pore. In Mollienesia Sp. the anterior pore in tubular while in G. auratus auratus a rim is present. In G. auratus auratus a nasal flap is found which deflect water towards the anterior pore. No relationship is established between the presence of a tubular opening and macrosmat nature of the fish. The shape of rosette is oval in G. auratus auratu and triangular in Mollienesia Sp. The olfactory rosette of G.auratus auratus is placed under Bateson's (1889) rosette type 3 and Burne (1909) rosette column I.

The number of lamellae increases with the size of the fish in G. auratus auratus. A central raphe is also present in G. auratus auratus. The olfactory rosette of Mollienesia S is fleshy textured and devoid of lamellae. Accessory nasal sacs are absent in both fishes. No ecological or phyletic correlation is found between the presence or absence of the accessory sacs. The unidirectional flow of water current is present in G. auratus auratus and be categorised under isosmat

The olfactory chamber in G. auratus auratus splits up due to linguiform process, into central and peripheral parts. The olfactory areas are found to be 47 mm^2 (55 mm TL) and 1.62 mm^2 (37 mm TL) in G.auratus auratus and Mollienesia sp.

respectively. *G. auratus auratus* is necrosmat while *Mollienesia* Sp. is microsmat and can be placed under Tiechman's (1954) group 3 and group 1, respectively. The olfactory nerve of both *G. auratus auratus* and *Mollienesia* Sp. is sessile type.

Histologically, the olfactory epithelium of *G. auratus auratus* is composed of receptor cells, supporting cells, basal cells and goblet cells. The neurons run in the central lamellar space and form dendritic supply to the olfactory epithelium. The goblet cells are interspersed in the olfactory epithelium. The neurons unite to form the olfactory nerve which establishes a synaptic contact with the olfactory bulb. The hepatic parenchyma of *Mollienesia* Sp. and *G. auratus auratus* consists of continuous masses of cells forming cords which get separated by blood sinusoids. Polyhydral hepatocytes possess a well defined cell membrane and nucleus.

The pollutant induced histopathology of the olfactory rosette of *G. auratus auratus* show that the goblet cells are more severely effected and the epithelial cells exhibit disruption in cytoplasmic material due to vacuolization.

The hepatocytes of copper sulphate treated fishes show vacuolization and condensation of cytoplasm. A gradual increase in damages is noticed with larger duration of exposure alongwith necrosis of hepatocytes and coagulation of blood in sinusoids.

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